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Electric Vehicle Design and Simulation

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Abstract: *The need for modelling and simulation of hybrid electric vehicles (HEVs) is discussed in this study. Examples of power train component and system modelling are shown alongside various modelling approaches. This study presents the modelling and simulation of the hybrid electric vehicle (HEV) using MATLAB/Simulink. The purpose of this simulation tool is to aid in the design and assessment of the hybrid electric car. Driveline components can be changed, and the impact on a hybrid electric vehicle's efficiency can be researched. Both simulation tools use a Simulink vehicle model, in which the driveline parts are modelled as interconnected blocks that exchange physical signals on a second-by-second basis. In the demonstration, the HEV's various operational modes—accelerating, cruising, charging the battery while accelerating, and regenerative braking—are displayed over a full cycle.*

Keywords: Modelling and simulation of hybrid electric vehicles; simulation of hybrid vehicles; and physics-based modelling

I. INTRODUCTION

Internal combustion engines (ICE) and electric motor/generators (EM) are arranged in series or parallel to power hybrid electric vehicles (HEV). While the EM improves efficiency and fuel economy by recovering energy during braking and storing extra ICE energy during coasting, the ICE extends the vehicle's driving range. According to many HEV initiatives, fuel economy increased by 20% to 40% (Zhou, 2005). As can be seen in Figure 1, HEV offers a possible remedy for the energy shortage. In order to optimise the operating parameters for every given driving state, such powertrains' design and control entail modelling and simulation of intelligent control algorithms and power management methods (Zhou, 2005).HEVs often fall into one of two fundamental categories: series hybrids or parallel hybrids (Zhou, 2005). In a series HEV, a generator is used to first convert the ICE's mechanical output to electricity. Either the battery is charged by the converted electricity, or the battery is bypassed in favour of an electric motor to drive the wheels. This electric motor is also used to store braking energy. A parallel HEV, on the other hand, uses clutches to connect both the ICE and the electric motor to the wheels' final drive shaft.With this set up, the ICE and electric motor can drive the wheels simultaneously, separately, or both simultaneously. Regenerative braking and collecting the ICE's extra energy while coasting are other uses for the electric motor. To increase power output and fuel efficiency, series-parallel and complicated HEV have recently been created (Zhou, 2007). Simulating and modelling processes help in the design of HEV powertrains. In many studies (Filippa et al., 2005; He and Hodgson, 2002a, 2002b; Barbarassi et al., 2005), models and control algorithms were put out and implemented. Using simulation tools like MATLAB/Simulink, problems with battery modelling, torque management, control algorithms, and vehicle simulation were solved. For these uses, it is simple to find computer models (Paganelli et al., 2001). Two general HEV challenges, including cutting-edge powertrain topologies and sophisticated energy storage devices, were examined in this study.In order to discover the best design for a given application, comparisons were done. Vehicle simulation software was examined. The modelling tools MATLAB/Simulink and Modelica/Dymola were specifically introduced. Throughout this study, several simulation tools were extensively used.

II. MODES OF OPERATION

The architecture shown in Figure 2 allows for a variety of operating modes for the vehicle. In Table 1, these operational modes are summarised. The HEV operates in both hybrid and conventional modes during a normal driving mission (Zhou, 207).This is shown in the table below from the battery and helps the ICE drive the vehicle when it is in four-wheel drive. Similar choices are available when the ISA is in regular mode. In essence, the 4WD mode is just a

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variation of the standard mode, with the ISA and EMmotor supplying the necessary electrical power (in a series/parallel hybrid configuration). When the driver applies the brakes to slow down the car, the car goes into deceleration mode. 'Regenerative braking' is used in this situation. Regenerative braking is the method of producing electricity to recharge the battery by exploiting the resistance between the EM field and armature. The mechanical braking system does not engage as the driver presses the brakes for a certain amount of pedal travel, and the EM instead absorbs torque from the rear axle. According to He and Hodgson (2002b), this mechanical energy is transformed into electrical energy and delivered to the battery. Each of these results in much lower emissions and higher fuel efficiency. The ICE is shut off while the vehicle is in idle mode and when decelerating, unless the battery needs to be recharged and this is necessary to drive the ISA to supply the required power (series HEV). By merely stopping the fuel flow to the ICE during braking and idle conditions, the fuel efficiency can rise by as much as 10% (Barbarisi et al., 2005). The fundamental principle that the EM should be used during launch and immediate power request conditions is accompanied by this idea (He and Hodgson, 2002b). This is due to the fact that electric actuators can provide great torque at low speeds without releasing any toxic by products into the environment. When the vehicle's EM motors are turned on during electric launch mode, this basic rule is met. During engine start mode, the ICE comes on after a certain speed (Ohlemmacher et al., 2005). When the ICE reaches its maximum speed, the automated gearbox activates, making the ICE the main actuator for the vehicle's propulsion system. The car now switches to its regular mode. The HEV fits the requirements for being a parallel HEV by operating in both the electric launch and normal mode, as previously specified. Keep in mind that the EM can be used in normal mode to take power from the battery as well as to supply it with regenerative power.

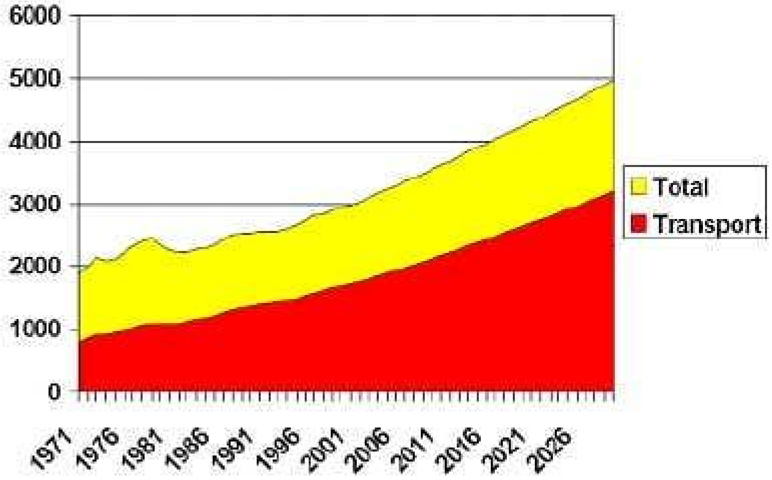

Figure 1 Globe oil consumption perspective

III. MODEL OF THE DRIVELINE

Figure 2 illustrates the driveline's dynamic model. For a list of the nomenclature, see Table 2 of the Appendix. The model just contains the necessary inertias. For the sake of simplicity, the inertias of the smaller parts (the axles, braking assemblies, and wheels) do not significantly affect the dynamics of the system and can be disregarded. To further simplify the model, unnecessary damping and spring effects, such as those inherent to the automated gearbox and rear gearbox, are also removed. Since these dynamic impacts are negligible in relation to other driveline components (such as ICE, EM, and ISA), disregarding them has no impact on the model's accuracy (Musardo and Staccia, 2003). The following equations were created by the authors as well as individually.

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Table 1 Vehicle operating modes

Mode	*ICE*	*ISA*	*EM*	*Tran.*
Idle	Off	Off	Off	Neutral
ICE, EM, and ISA are shutoff, electrical accessories.				
Electric launch	Off	Mot.	Off	Neutral
Vehicle started from rest with EM.				
Engine start	Start	Mot.	Mot.	Neutral
At a certain vehicle speed, ICE quickly started by ISA.				
Normal	On	Mot. or gen.	Mot. or gen.	Drive
Torque requests determined by primary control strategy.				
Deceleration	On or off	Gen.	Gen.	Drive or neutral
Regenerative braking by EM and ISA as battery allows.				
4WD	On	Gen. or off	Mot.	Drive
EM receives continuous power through DC from ISA.				

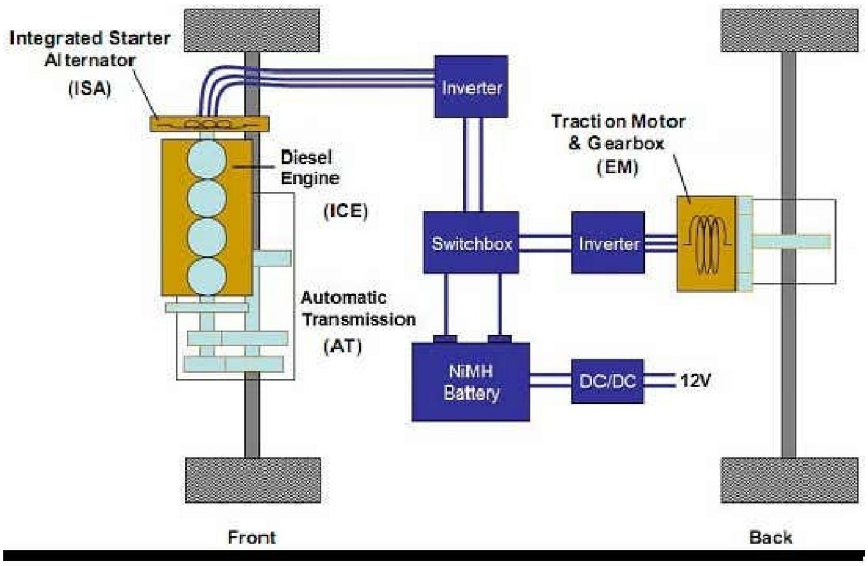
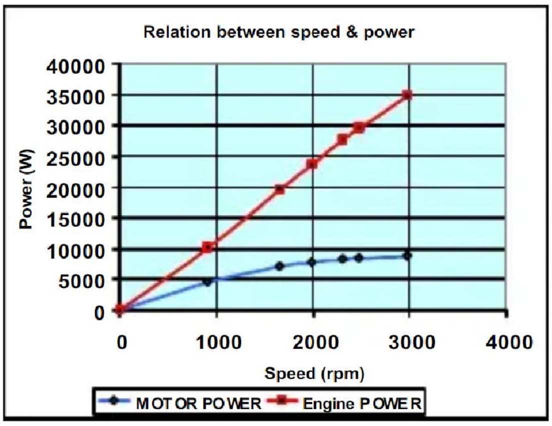
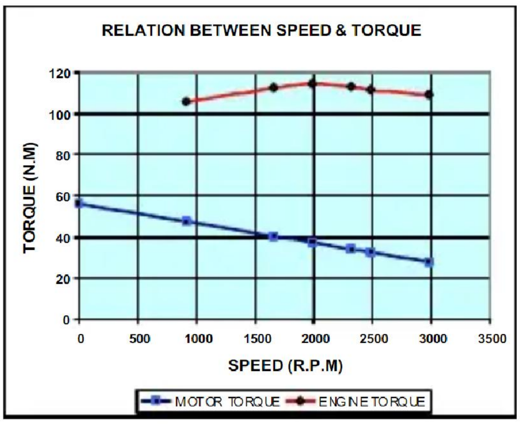


Figure 2: Architecture of Electric Vehicle

There are different between the hybrid microbus performance and the ICE microbus this difference will be shown in the plot of the relation between the speed and power for two microbuses and the speed and torque relation Figure 4.





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IV. VEHICLE SIMULATION TOOLS

The development of a hybrid powertrain depends on simulation-based research of vehicle performance because it is impracticable to validate designs using expensive prototypes. Because it is inconvenient to use so many different modelling techniques separately, integrated modelling tools are needed to expedite and enhance the accuracy of the modelling process.Vehicle simulation is a technique for quickly and methodically examining various design possibilities (fuel selection, battery, gearbox, fuel cell, fuel reformer, etc.) during the design and development of a vehicle. There are currently a number of simulation programmes based on various modelling platforms, but none of them are adequate to mimic all design alternatives. These tools always concentrate on a single application and narrowly defined issues (Zhou, 2005).A quick, accurate, and versatile simulation tool is still being developed after years of ongoing advancements. MATLAB/Simulink and Modelica/Dymola are two of the most used platforms for vehicle modelling and analysis (Ohlemmacher et al., 2004a).

V. HEV POWER TRAIN USING BATTERY MODEL

An HEV power train simulation based on Sim PowerSystems and SimDriveline is demonstrated in this example. According to Zhou (2007), the HEV power train is a series-parallel design. In order to improve the drive train efficiency and lower air pollution, this HEV has two different types of motive power sources: an electric motor and an ICE.It combines the benefits of an ICE (high dynamic performance and low pollution at high speeds) with the benefits of an electric motor drive (no pollution and high available power at low speed).

VI. SIMULATION RESULTS

In the demonstration, the HEV's many operating modes—accelerating, cruising, charging the battery while accelerating, and regenerative braking—are displayed throughout the course of a full cycle.Activate the simulation now. When you use the accelerator mode, it should run for roughly a minute. As you can see, the HEV's speed starts at 0 km/h, increases to 73 km/h after 14 s, and then drops to 61 km/h after 16 s. This outcome is achieved by holding the accelerator pedal constant at 70% for the first four seconds, 10% for the following four seconds when it is released, 85% when it is pushed again for five seconds, and ultimately set to -70% (braking) until the simulation is complete.In the main system, select the scope "car."The following details what transpires while the HEV is in motion:

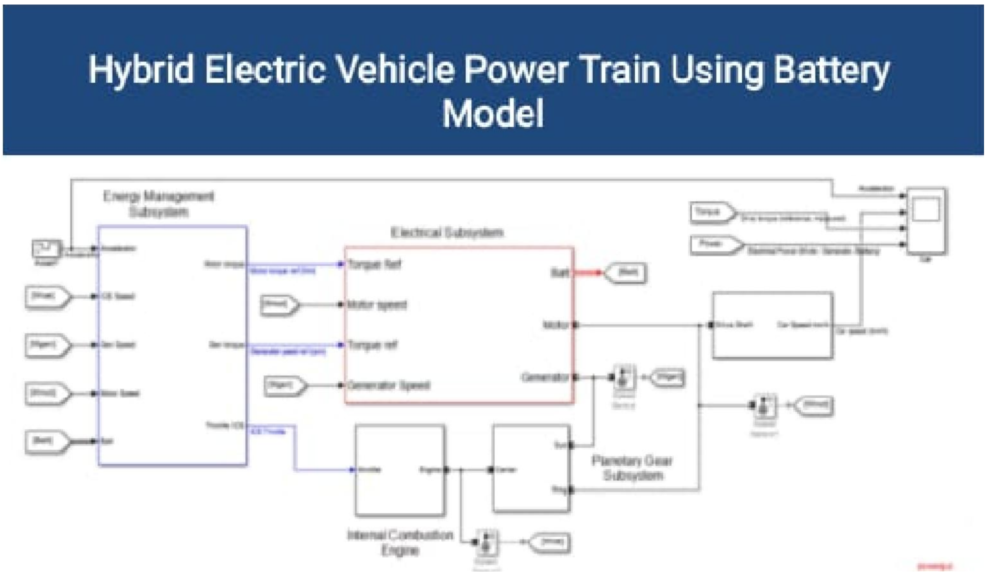

Figure 4 Simulation model in Simulink for HEV power train model

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6.1 Electrical Subsystem

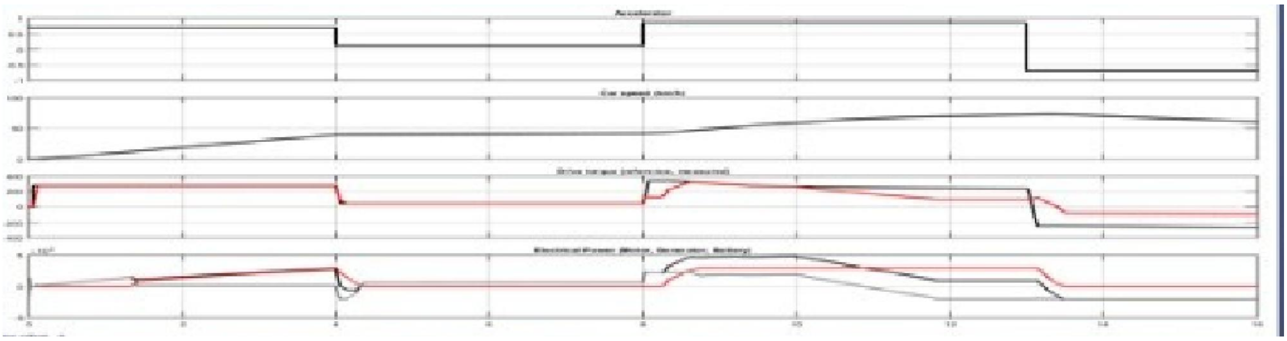

Figure 10 Acceleration and speed

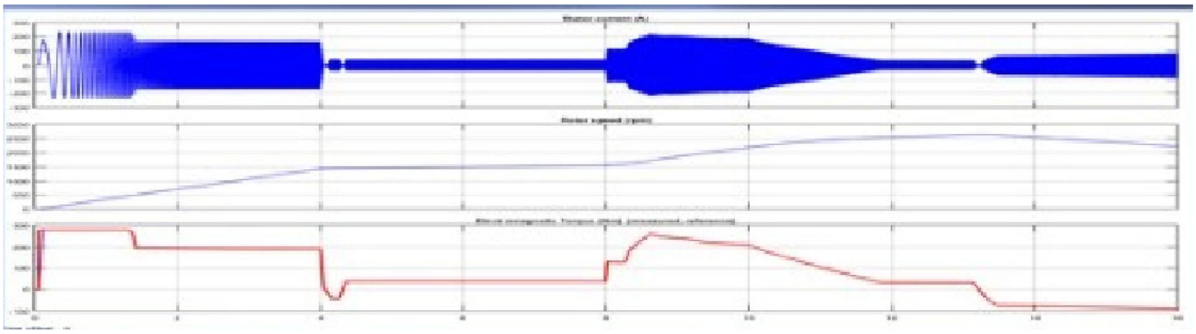

Figure 11 Electrical parameters of motors

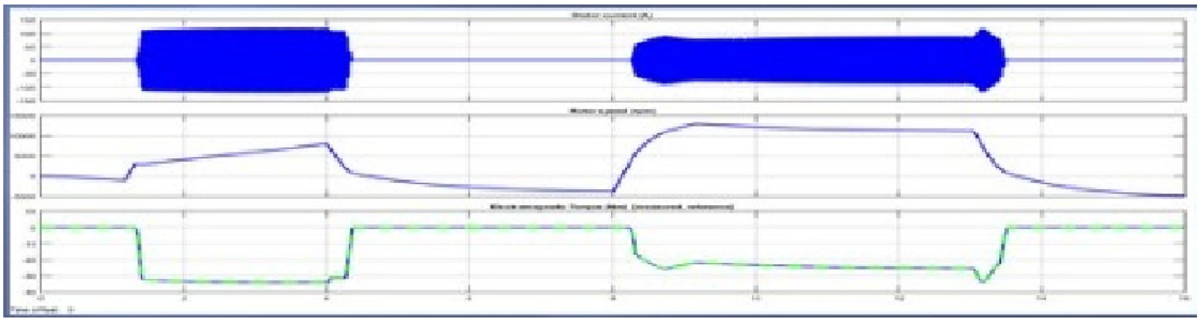

Figure 12 Electrical parameters of generator

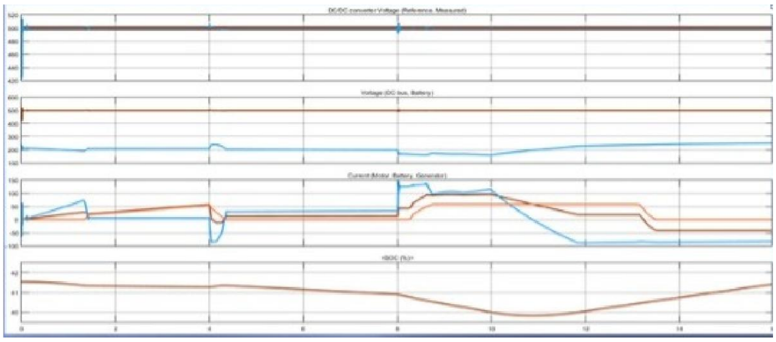

Figure 13 Electrical measurements

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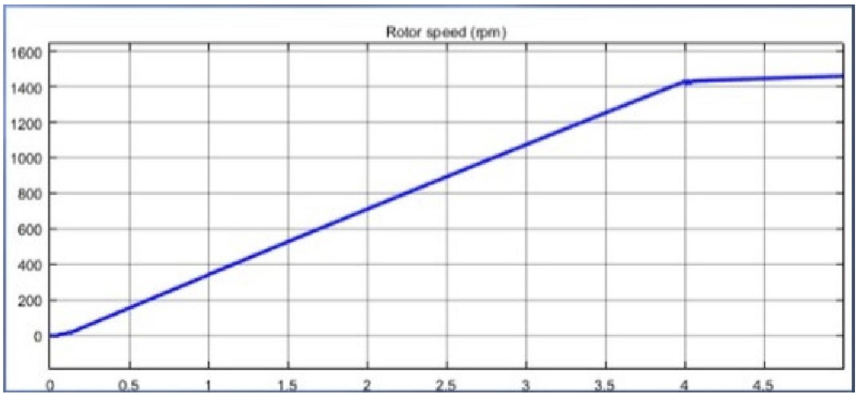

Figure 14 Distances travelled km/hr

VII. CONCLUSION

An overview of the modelling and modelling of HEVs was provided in this work. Examples of powertrain component and system modelling are used to illustrate various modelling techniques. This simulation tool is intended to assist in the development and assessment of the HEV. The driveline's components can be changed, and the impact on HEV fuel efficiency can be studied. Both simulation tools use a Simulink vehicle model, in which the driveline parts are modelled as interconnected blocks that exchange physical signals on a second-by-second basis. A vector holding the vehicle reference speed as a function of time is the simulation input. Any simulated signal that is desired can be the output. In each scope, some intriguing observations can be made. You can see the electrical system's DC bus voltage, which is well-regulated at 500 V, throughout the whole simulation. The power law of the planetary gear is equal to zero during the whole simulation in the planetary gear subsystem, and the Willis relation is equal to -2.6.

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BIOGRAPHY

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